# Integrated Endurance and Resistance Exercise Countermeasures Using a Gravity Independent Training Device

Completed Technology Project (2008 - 2012)

## Project Introduction

Extended space flight as well as existence on Mars will require exercise equipment and training protocols designed to maintain physical fitness and general health. NASA has determined that current flight rated exercise hardware is not appropriate for use on the future Crew Exploration Vehicle (CEV) (JSC--Johnson Space Center--SAT Report 12/06). Studies will investigate protocols designed to maintain both cardiovascular and musculoskeletal fitness using a gravity independent multi-mode exercise device (M-MED), which has been identified by NASA as potential flight hardware. M-MED can provide either high resistance strength- or low resistance endurance-mode exercises.

Phase I -ground based integrated strength & cardiovascular (CV) exercise training under normal weight bearing conditions.

Phases 2&3 - application of this protocol with progressive levels of inactivity.

Measurements - total body physical work capacity, muscular mass, strength, and sustained muscle endurance (i.e., extravehicular activity, EVA, related issues). CV-related exercise using M-MED "aerobic" mode configuration designed to minimize the time spent in exercise using high power output, short duration interval training. On alternate days, the M-MED will be configured for strength training which has been shown to result in increased muscle strength and size. These studies will validate the efficacy of concurrent endurance and strength training as a high economy approach to flight crew physical fitness, using a scientifically proven exercise modality that has a high probability for use during prolonged space flight missions. This work directly addresses primary requirements in the National Space Biomedical Research Institute (NSBRI) Request for Applications (RFA):

1. "New, innovative exercise hardware for deployment on CEV and Martian surfaces that provide efficient means for maintenance of aerobic capacity, bone and muscle strength, and endurance with sufficient reserve for contingencies."

2. "New, innovative exercise protocols that minimize in-flight crew time necessary to maintain aerobic capacity and muscle strength and endurance, and facilitate reserve for contingencies on lunar and Martian missions."

## Anticipated Benefits

To date, this project has demonstrated that a very modest amount of time invested in exercise using the multi-mode exercise device (M-MED) can produce substantial increases in muscle function and cardiovascular fitness. In particular, the fact that M-MED based exercise induces performance gains at many movement speeds suggests that it may be superior to more traditional methods. In total, these findings show that this equipment and these protocols developed specifically for space flight related application may provide a basis


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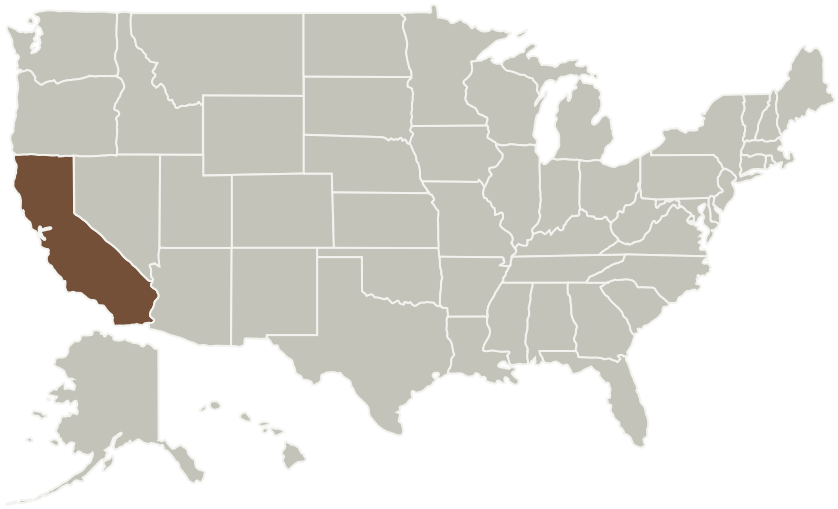
for broader use in situations where space and time constraints may limit access to effective exercise.

### Primary U.S. Work Locations and Key Partners



| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| National Space Biomedical Research Institute(NSBRI) | Lead Organization | Industry | Houston, Texas |
| University of California-Irvine | Supporting Organization | Academia | Irvine, California |

| Primary U.S. Work Locations |
|---|
| California |

### Project Transitions

**June 2008:** Project Start

## Organizational Responsibility

**Responsible Mission Directorate:**

Space Operations Mission Directorate (SOMD)

**Lead Organization:**

National Space Biomedical Research Institute (NSBRI)

**Responsible Program:**

Human Spaceflight Capabilities

## Project Management

**Program Director:**

David K Baumann

**Principal Investigator:**

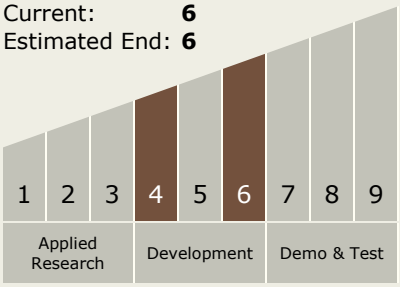
Gregory R Adams

**Co-Investigators:**

Vincent Caiozzo
Kenneth M Baldwin

## Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



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**September 2012:** Closed out

**Closeout Summary:** This study is designed to investigate the effectiveness of a new exercise device, multi-mode exercise device or M-MED, for use during long-duration space flights for the maintenance of cardiovascular and musculoskeletal fitness of astronauts. The M-MED is gravity independent and provides both the h igh force resistance and low force rowing type resistance. To date the results ind icate that foot forces in resistance mode exercise on M-MED are similar to those seen using free weight exercises. Electromyography (EMG) studies demonstrate that similar activation levels are seem in key muscles during either M-MED base d or free weight resistance exercise. EMG during rowing demonstrate that the th igh, leg, and arm muscles are robustly activated. Endurance mode exercise was also found to stimulate recruitment of the muscles which support the spine. In a recently completed study, 32 subjects (16 male, 16 female) completed 5 weeks of combined resistance and endurance training using the M-MED. Muscle strengt h increased ~20% while aerobic fitness measured as maximal oxygen consumpt ion (VO2max) increased ~8%. M-MED training increased time to hand grip fatig ue by ~70% and leg extension fatigue by ~27%. Thigh muscle cross sectional a rea increased ~11% as a result of training. Additional deliverables include cross validation of VO2max testing results between the M-MED device and laboratory standard cycle ergometry based testing protocols. As requested by NASA, additi onal studies have demonstrated that M-MED based exercise can increase the siz e and strength of the calf and hamstrings muscle groups. These results demonst rate that the M-MED device can be used for both training and physical work cap acity testing providing a platform for in-flight assessment. In summary, findings to date indicate that the gravity independent M-MED is a viable option for resist ance- and endurance-mode exercise during flight and/or planetary exploration t hereby addressing two critical risks: 1) Cardiovascular deconditioning; 2) Decre ased muscle strength, endurance, and size (atrophy). Endurance mode exercise may have the added benefit of maintaining and, possibly, improving endurance of arm muscles of flight crews as well as aiding in the maintenance of lower bac k stability and loading during flight and planetary exploration. Presentations at workshops and meetings are listed below and also in the Bibliography section: C ountermeasure Exercise Using a Single, Gravity Independent, Device to Prevent Cardiovascular and Muscular Deconditioning. J. Cotter, T. Owerkowicz, F. Hadda d, P. Tesch, V. Caiozzo, G. Adams. American Society for Gravitational and Space Biology Annual Meeting, 2011. Resistance and aerobic flywheel training improve s muscle strength and aerobic capacity in ambulatory subjects. Owerkowicz T, C otter JA, Yu AM, Camilon ML, Hoang T, Baker MJ, Pandorf C, Kreitenberg A, Bald win KM, Tesch PA, Caiozzo VJ, Adams GR. 18th Humans in Space symposium of the International Academy of Astronauts. Houston, TX, 2011. Gravity-independe nt flywheel exercise training improves aerobic capacity and muscle strength in a mbulatory subjects. Owerkowicz T, Cotter JA, Tesch PA, Caiozzo VJ, Adams GR. Experimental Biology Washington, DC, 2011 DNA Methylation is Altered in Huma n Skeletal Muscle in Response to Exercise Training. Shlomit Radom-Aizik, Fadia Haddad, Tomasz Owerkowicz, Joseph M. Devaney, Eric P. Hoffman, Per A. Tesc h, Gregory R. Adams. American College of Sports Medicine Annual Meeting, 201 2 Influence of 10 days of unilateral lower limb suspension and combined exercis e training on human vastus lateralis and soleus muscles. J. Cotter, F. Hadad, A. Yu, T. Hoang, M. Baker, P. Tesch, K. Baldwin, V. Caiozzo, G. Adams. Experiment al Biology Annual Meeting, 2012. The presence and regulation of antisense long non-coding RNA with altered myosin expression in exercising human muscle. Cla y E. Pandorf, Fadia Haddad, Tomasz Owerkowicz, Kenneth M. Baldwin, Vincent J. Caiozzo, Gregory R. Adams. Experimental Biology, 2012. The Effects Of Muscl

## Technology Areas

**Primary:**

- TX06 Human Health, Life Support, and Habitation Systems
  - TX06.3 Human Health and Performance
    - TX06.3.2 Prevention and Countermeasures

## Target Destinations

The Moon, Mars

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## Stories

Abstracts for Journals and Proceedings
*(https://techport.nasa.gov/file/44436)*

Abstracts for Journals and Proceedings
*(https://techport.nasa.gov/file/44433)*

Abstracts for Journals and Proceedings
*(https://techport.nasa.gov/file/44431)*

Abstracts for Journals and Proceedings
*(https://techport.nasa.gov/file/44429)*

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*(https://techport.nasa.gov/file/44438)*

Articles in Peer-reviewed Journals
*(https://techport.nasa.gov/file/44437)*

Articles in Peer-reviewed Journals
*(https://techport.nasa.gov/file/44439)*

## Project Website:

https://taskbook.nasaprs.com